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Suitability Evaluation of the Forest Resource Inventory Method in Lao People's Democratic Republic

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Abstract
In this study suitability evaluation of the forest inventory method is needed for establishing sustainable forest management plans in the production forest areas of Lao PDR. In the year 2010, Laos PDR accepted new forest survey method to change the sampling intensity from 3.0% to 0.625% in order to save time and cost. So this study is aiming to evaluate the appropriate sampling intensity for forest resources inventory in Lao People Democratic Republic. To find out the appropriate sampling intensity, the four sampling intensities were chosen, such as past 3%, current 0.625%, and newly 0.75% and 1.5%. And these four sampling intensities were applied to the evergreen forest compartments of Production Forest Management Area, which is one of the three forest categories in Lao PDR. The sample plot size of 600 m^2 (20m X 30m) was used for measuring the diameter at breast height (DBH) ($\geq$ 15 cm) of all the trees equally to the all the sampling intensities. The research results revealed that the 0.75 and 1.5% sampling intensities (newly proposed) were not significantly different to 3.0% (the traditional one). On the other hand, the current sampling intensity (0.625%) was significantly different in comparison to the rest of the sampling intensities (0.75, 1.5, and 3%). Changing sampling intensity from 0.625 to 0.75 and 1.5% may certainly reduce the errors encountered due to the size of the sampling unit. In contrary, changing the intensity from 3% to the newly proposed 0.75 and 1.5% may reduce the time and cost incurred to maintain the inventory. In all, these research results implicate to provide an opportunity to replace the past and current two, such as non-representative 0.625% and cost-taking 3.0%, sampling intensities to the newly proposed 0.75% level of sampling intensities for forest resources survey of Lao PDR.
Keywords: Forest management planning, Forest inventory, compartment, sampling intensity

I. Introduction

Forest inventory is a process for obtaining data collection on the quality and quantity of forest resources and forms the foundation of forest planning and forest policy (Kohl *et al*., 2006). Described forest inventory as the activity of data collection that helps to generate the required information base on the forest resource within an area of interest and a tool that provides the information about size and shape of the area (Zerihun and Yemiru, 2013). The goal of the National Forest Inventory is to record the current state and recent development of the forest in a representative and reproducible manner, using various data sources (Peter and Heike, 2001). The forest inventory module is intended for people involved in the collection of data on forest resources. It provides insights into the types, purposes and main steps of forest inventories from measurement methods to data collection (Husch, 1971). National forest assessments are attracting increasing attention owing to their role in providing information related to manifold forest functions (Tewari, 2016).

Understanding the techniques used to measure trees and stands provides landholders with the opportunity to make better management decisions by measuring trees or plots (Reid and Stephen, 1999). And forest measurements can be considered for forest management; the role of measurement is to supply the numerical data required to make prudent management decisions (Thomas and Harold, 2002). Evaluate the efficiency of the different sampling approaches using a factorial design, the factors being intensity, area and volume of trees, sampling error and coefficient of variation (Bogdan, 2013). Systematic random sampling is usually preferred over simple random sampling. This type of probability sampling is also called as ordinary or pseudo-simple random sampling (Bobbie, 2007). Forest inventories conducted under the auspices of the national FIA Program have been commodity oriented in general, with emphasis on estimating the area and volume of the Nation’s timber supply (William *et al*., 2005).

The first step is to develop an appropriate forest inventory that describes land and forest use method so as to highlight the status and change of forest cover as well as to put efforts to upgrade and develop the capacity of the Department of Forestry (Lao-Swedish Forestry Cooperation Programme, 1987). The sustainable forest management plan encompasses the country’s experience in the management of production forests area (PSFM Operations Manual, 2016). A model analysis is performed to determine: the proportion of the national forest resource for Production Forest Management (PFM), Village Forest Management (VFM), and Government Forest Management (GFM) (Word Bank, 2011). Forestry Strategy 2020 of Lao Government is to contribute to achieve the indicative targets of the national socio-economic plans, to provide goods and services to the national economy and to the society, to reduce dependence and increase concrete efforts to manage sustainably the country's natural resources, and to con-tribute to the implementation of the national growth and poverty eradication strategy (Prime Minister's Office, 2005).

Managing forests sustainably means increasing their benefits, including timber and food, to meet society's needs in a way that conserves and maintains forest ecosystems for the benefit of present and future generations (FAO, 2018). Forests are managed for timber production and for maintaining tree species. A subtle shift from multiple-use management to ecosystems management is being observed and the new ecological perspective of multi-functional forest management is based on the principles of ecosystem diversity (Annika and Matti, 2006). The sustainable forest management has become an issue in the past decade, in the concerns of overexploiting the resource (Robert, 2003). Forest management plan of Laos were consisting of various activities including survey, classification planning, research, logging and harvesting forest product surveys (National Assembly, 2007). Tropical forests are threatened by the distinctly different processes of deforestation and forest degradation (Simula *et al*., 2009). Investigation will pro-vide useful information to formulate appropriate policies to manage the forest resource efficiently on one hand and also address needs of the local people on the other (Josephat, 2014).

The purpose of the study was to identify the suitable sampling intensity in Production Forest Managements (PFMs). The specific objective was to compare the forest inventory at different sampling intensity of previously adopted (3.0 and 0.65%) and newly proposed ones (0.75 and 1.5%) in order to obtain the volume and number of trees per hectare to identify possible annual harvest areas.

II. Materials and Methods

2.1 Description of the study are

The study was conducted block 8 (1/15) of the Houykhoun Sub Forest Management Area (SFMA), Bolikhan Forest Management Area (FMA) of the Houysub-Namtex Production Forest Area (PFA), Bolikhamxay Province (Fig. 1). The six villages in the cluster participate in the management of the Houykhoun Sub-FMA from which selected block 8 as the forest inventory site using 3.0%, 1.5%, 0.75% and 0.625% sampling intensity. Six villages have a total population of 5,849 persons, including 2,850 females (48.7%), in 31 large extended families that are able to provide a labor force of 12 persons per family, on average. The villages rely mainly on farming and livestock raising for their livelihood.

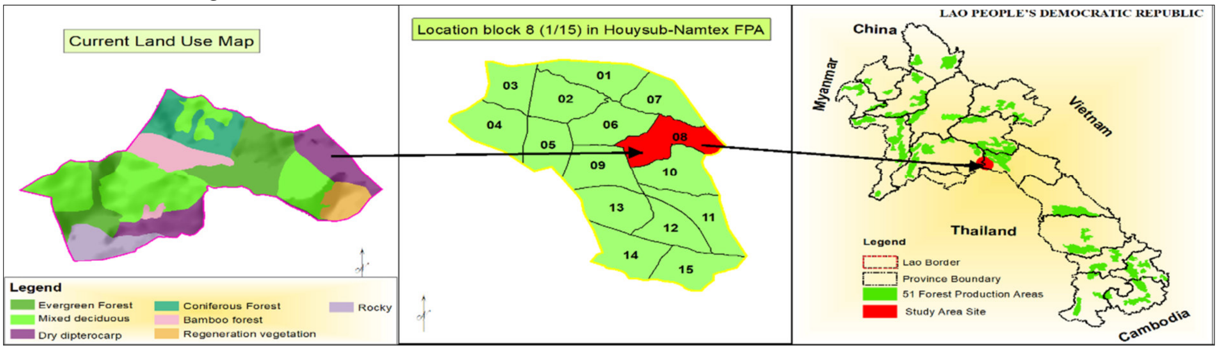


Fig.1. Study area in block 8 of the Houysub-namtext PFA site.

A total size of block 8 in the Houykhoun Sub-FMA of the Houysub-Namtext PFA. Was 641 hectares, the land use classifications there are 140.71 ha (or 21.95%) of evergreen forest, 231.52 ha (or 36.12%) of mixed deciduous, 83.59 ha (or 13.04%) of dry dipterocarp, 59.44 ha (or 9.27%) of coniferous forest, 51.37 ha (or 8.015) of bamboo forest, 30.35 ha (or 6.87%) of regeneration forest and 44.03 ha (or 6.87%) of rocky.

Table 1: Area of production forest in the difference sampling intensity

		Area (ha)	Percent (%)
1.	Inventory at 3.0% sampling intensity	Area (ha)	Percent (%)
1.1	Harvestable production forest (≥60m^3/ha)	394.44	61.54%
1.2	Regenerating production forest (40-60m^3/ha)	46.68	7.28%
1.3	Degraded production forest (≤40m^3/ha)	48.55	7.57%
2.	Inventory at 1.5% and 0.75% sampling intensity	Area (ha)	Percent (%)
2.1	Harvestable production forest (≥60m^3/ha)	346.87	54.11%
2.2	Regenerating production forest (40-60m^3/ha)	94.25	14.70%
2.3	Degraded production forest (≤40m^3/ha)	48.55	7.57%
3.	Inventory at 0.625% sampling intensity	Area (ha)	Percent (%)
3.1	Harvestable production forest (≥60m^3/ha)	316.62	49.39%
3.2	Regenerating production forest (40-60m^3/ha)	83.59	13.04%
3.3	Degraded production forest (≤40m^3/ha)	89.46	13.96%
	Total:	489.67	76.39%

Table 1 shown **forest zones** areas, from which 489.67 hectares (or 76.39%) were considered for data collection, which includes harvestable production forest compartments, regenerating forest compartments and degraded production forest compartment.

The area of production forest area at different sampling intensity (3.0%, 1.5%, 0.75% and 0.625%) were the same in size while other types of forest zones were different.

And another hand, the area of protected forest of 151.33 ha (or 23.61%) were not considered for the data collection (Table 2). Which includes protection forest (riparian buffer) of 25.58 ha, (or 3.99%), 81.72 ha (or 12.75%) of plantation and agroforestry and 44.03 ha (or 6.87%) of agriculture and non-forest.

Table 2: The area of non-forest in the different sampling intensity

No	Not data collection area	Area (ha)	Percentage (%)
1.	Protection forest	25.58	3.99%
1.1.	Protection forest (riparian buffer)	25.58	3.99%
2.	Plantation and Agroforestry	81.72	12.75%
2.1.	Fallow land for agroforestry	30.35	4.73%
2.2	Bamboo dominated forest	51.37	8.01%
3.	Agriculture and non-forest	44.03	6.87%
3.1.	Rock and open land	44.03	6.87%
	Total:	151.33	23.61%

2.2 Forest inventory design used

The data was collected from the natural forest stand in the Lao PDR based on-line plot systematic sampling method (Table 3). As it's the natural forest stand, the density and number of trees were different, with the possibility of getting different number from different plots, as there was no uniform distribution and spacing of trees; due to the reason, density, volume and number of tree in each sample plot of compartment is not equal. In the evergreen forest compartments evaluation of sampling intensities were made by comparing the existing sampling methods (3% and 0.625%) with the newly proposed sampling methods (1.5% and 0.75%) to get a better method of sampling for the stand harvesting process.

Table 3: Forest inventory designs at the difference sampling intensity

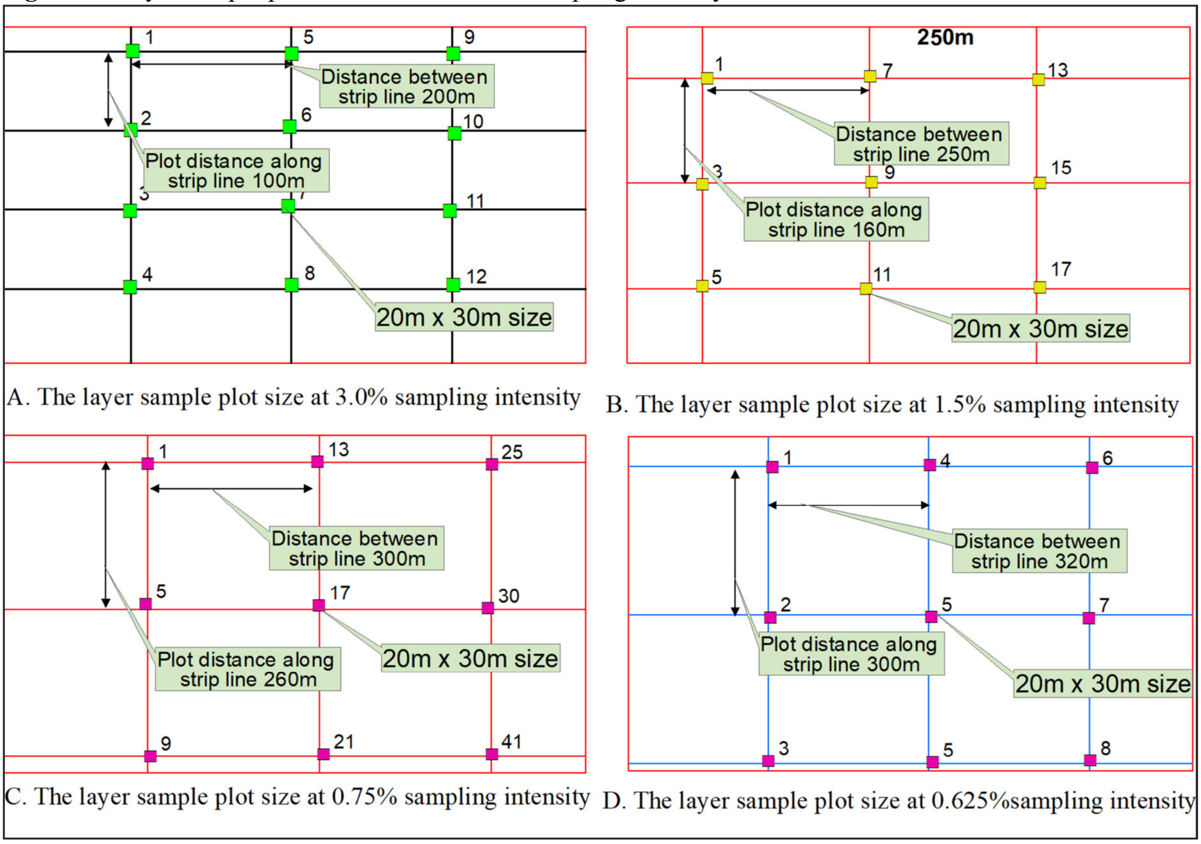
DBH of trees measured (cm)	≥15	≥15	≥15	≥15
Plot dimension, (m x m)	20 x 30	20 x 30	20 x 30	20 x 30
Plot area (m³)	600	600	600	600
Distance between strip (m)	200	250	300	320
Plot distance along strip (m)	100	160	260	300
Area covered by 1 plot (m²)	20,000	40,000	78,000	96,000
Sampling intensity (%)	3.0%	1.5%	0.75%	0.625%

2.3 Measurement

Horizontal distances were measured using a 50m nylon rope line marked at 20m X 30m for the purpose of plot layout. North-South directions were determined using a field compass. The samples plot layout size in inventory at 3.0%, 1.5%, 0.75% and 0.625% sampling intensities, respectively (Fig. 2). A GPS device was used to determine the location on the ground of the reference point that was identified on the field map, diameter tape was used to measure DBH in cm, clinometer was used to measure the height of tree and bole height to measure the harvestable part of a tree in meter, respectively.

The samples plot of **20m X 30m** size (600m²) in the different sampling intensity was used for measuring all trees of the DBH>15cm and height in a systemically method, i.e. The local name of the tree, tree code, DBH class, total of height and quality of trees were determined (Appendix 1). Bole height was measured up to the main top branch and with at least 15 cm in diameter.

Fig. 2. The layer sample plot size in the different sampling intensity



A. The layer sample plot size at 3.0% sampling intensity B. The layer sample plot size at 1.5% sampling intensity

C. The layer sample plot size at 0.75% sampling intensity D. The layer sample plot size at 0.625%sampling intensity

2.3 Data analysis

The forest inventory plots in each production forest compartment were considered the samples. Statistical analyses were conducted to provide estimates of the mean stand volume, standard deviation, and standard error of the mean, confidence interval of the mean stand volume of each production forest compartment. The analyses data was using forest compartment (management units) of a forest. Whole forest area was divided in to various compartments and each compartment was identified with a number on the operational map.

2.3.1 Formulas used in data analysis

1. Volume per hectare in each plot

$$V_{plot} = \frac{(\text{Vol Tree1} + \text{Vol Tree2} + \cdots + \text{Vol Tree x})}{0.06\, ha\ (the\ area\ of\ the\ sample\ plot)} \quad \ldots\ldots(1.1)$$

Which is calculated for the ≥15 cm DBH class. Where: V_{plot} is average stand volume in each sample plot (m³/ha), Voltree1, $Vol_{tree}2 \ldots Vol_{tree}$ x are the average volume per plots 1, 2…n, respectively, and 0.06 ha is area of the sample plot using (Husch *et al*., 2002).

1.1. Volume per hectare in each compartment

$$V = \frac{V1+V2+\cdots+Vn}{n} \quad \ldots\ldots(1.2)$$

Which is calculated for each DBH class in the block. Where: $V_1, V_2 \ldots V_n$ are the average volume per hectare of plots 1, 2…n, respectively, and n is the number of plots in the compartment (Julie *et al*., 2013).

1.2. Volume per hectare in each block

$$V = \frac{A1*V1 + A2*V2+\cdots+Am*Vm}{A1+A2+\cdots+Am} \quad \ldots\ldots1.3$$

Which is calculated for the each DBH class in the block. Where: A1, A2 … Am are the area of compartments 1, 2…m, respectively, and $V_1, V_2 \ldots V_m$ are the average volume per hectare of compartments 1, 2…m, respectively (Husch *et al*., 2002).

2. Number of trees per hectare in each plot

$$T = \frac{\text{Number of Trees in the plot at DBH class}}{0.06\, ha\ (the\ area\ of\ the\ sample\ plot)} \quad \ldots\ldots(2)$$

Calculated for trees in the >15 cm DBH classes (T/ha) using (Husch *et al*., 2002).

2.1. Number of trees per hectare in each compartment

$$T = \frac{T1+T2+\cdots+Tn}{n} \quad \ldots\ldots (2.1)$$

Where: T_1, $T_2 \ldots T_n$ are the average number of trees per hectare of plots 1, 2…n, respectively, and n is the number of plots in the compartment (Julie *et al.*, 2013).

2.2. Average number of trees per hectare in each block

$$T = \frac{A1*T1 + A2*T2+\cdots+Am*Tm}{A1+A2+\cdots+Am} \quad \ldots\ldots (2.2)$$

Calculated for each DBH class in block. Where: A1, A2 … Am are the area of compartments 1, 2…m, respectively, and T_1, $T_2 \ldots T_m$ are the average number of trees per hectare of compartments 1, 2…m, respectively (Husch *et al.*, 2002).

3. Standard deviation

$$S = \sqrt{\frac{(V1-MV)(V1-MV) + (V2-MV)(V2-MV) + \cdots + (Vn-MV)(Vn-MV)}{n-1}} \quad \ldots\ldots (3)$$

Where: V1, V2 … V_n are the volume of compartments, MV is the mean volume of trees per hectare of compartments, and n is number of sample plot in each compartment, respectively (Rosie shier, 2004).

3.1. Standard Error

$$S_E = \frac{S}{\sqrt{n}} \quad \ldots\ldots (3.1)$$

Where: S is standard deviation of the mean volume per hectare of plots and n is the number of plots in the compartment (Am, 1982).

3.2. Simple t value

$$t = \frac{X}{SE} \quad \ldots\ldots (3.2)$$

With n-1 degrees of freedom. Where: X is sample mean and S_E is the standard error of the mean (Rosie shier, 2004).

3.3. Unpaired t value, for comparing two compartments samples

An unpaired t-test is used to compare two population means. The following notation will be used throughout this leaflet (Rosie, 2004).

Group	No	Mean	Std. deviation
Compartment 1	N_1	X_1	S_1
Compartment 2	N_2	X2	S2

$$S_P = \sqrt{\frac{(N_1-1)S_1^2+(N_2-1)S_2^2}{N_1+N_2-2}} \text{ is the pooled standard deviation} \ldots\ldots (3.3)$$

$$S_{E(X1-X2)} = S_P \sqrt{\frac{1}{N1} + \frac{1}{N2}} \text{ is the standard error of the difference between the means} \ldots\ldots (3.4)$$

$$\text{Unpaired } t = \frac{X1-X2}{SE(X1-X2)} \text{ with } N_1+N_2\text{-2 degrees of freedom} \ldots\ldots (3.5)$$

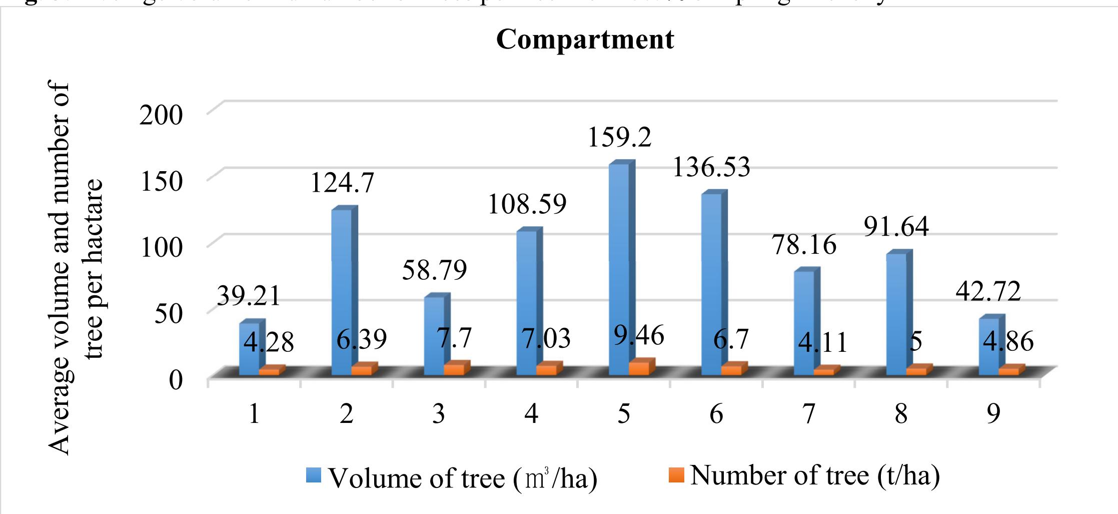
III. Results and Discussion

3.1. Identification of the volume and number of trees in different sampling intensities

3.1.1. The average volume and number of trees in the 3.0% sampling intensity

The average volume and number of trees per hectare in each forest compartment inventoried at 3.0% sampling intensity, respectively (Fig. 3). Compartments 2, 3, 4, 5, 6, 7 and 8 were shown the higher average volume of trees (≥60m³/ha), on the other hand, compartment 9 was shown the medium average volume of trees (40-60m³) and rest compartment namely 1 was shown the lower average tree volumes (≤40m³) per hectare, respectively.
Throughout the whole compartments (from 1-9), the number of trees were similar

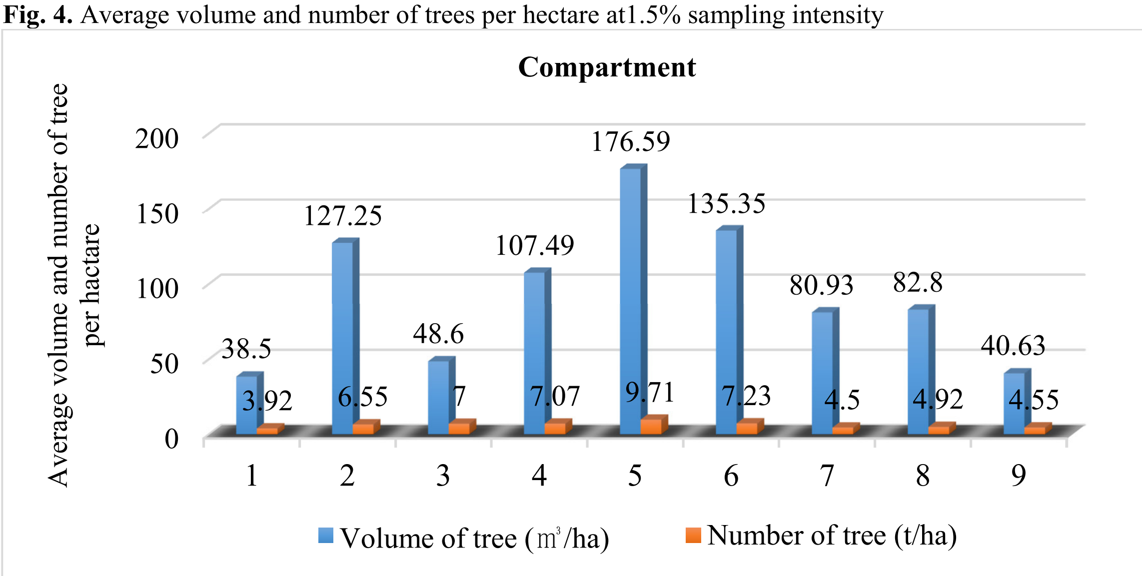
Fig. 3. Average volume and number of trees per hectare at 3.0% sampling intensity



3.1.2. The average volume and number of trees in the 1.5% sampling intensity

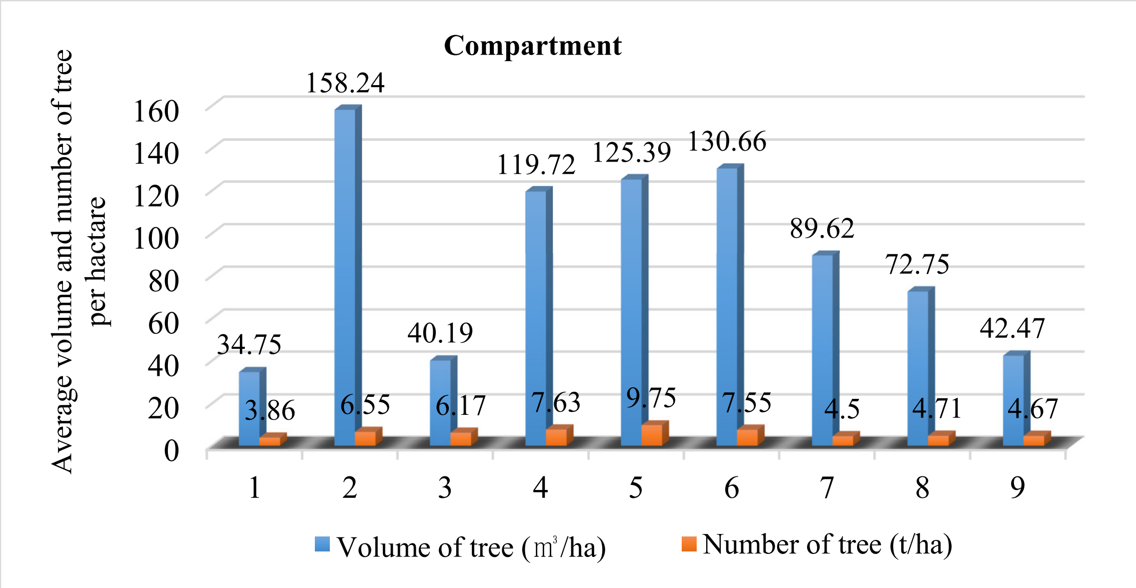
The average volume and number of trees per hectare in each forest compartment inventoried at 1.5% sampling intensity, respectively (Fig. 4). Compartments 2, 4, 5, 6, 7 and 8 were shown the higher average volume of trees (≥60m^3/ha), on the other hand, compartments 3 and 9 were shown the medium average volume of trees (40-60m³/ha), and rest compartment namely 1 was shown the lower average volumes of trees (≤40m³) per hectare. Throughout the whole compartments (from 1-9), the number of trees were similar.

Fig. 4. Average volume and number of trees per hectare at1.5% sampling intensity



3.1.3. The average volume and number of trees at 0.75% sampling intensity

Fig. 5. Average volume and number of trees per hectare at 0.75% sampling intensity



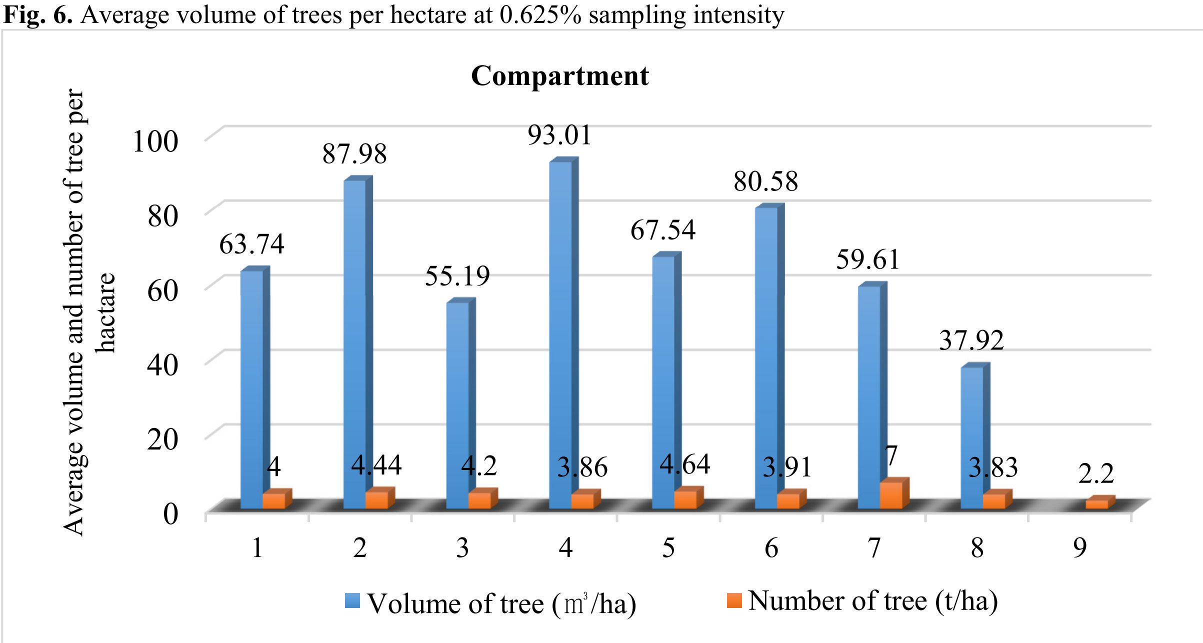
The average volume and number of the tree per hectare in each forest compartments at 0.75% sampling intensity, respectively (Fig.5). Compartments 2, 4, 5, 6, 7 and 8 were shown higher average volume of trees (≥60m^3/ha), and on the other hand, compartments 3 and 9 were shown medium average volume of trees (40-60m³/ha) and rest compartment namely 1 was shown lower average volumes of trees (≤40m^3) per hectare, respectively.

Throughout the whole compartments (from 1-9), the number of trees was similar.

3.1.4. The average volume and number of trees at 0.625% sampling intensity

The average volume and number of trees per hectare in the 0.625% sampling intensity, respectively (Fig. 6). Compartments 1, 2, 4, 5 and 6 were shown the higher average volume of trees ≥60m3 per hectare, on the other hand, compartments 3 and 7 were shown the medium average volume of trees (40-60m³/ha) and rest compartments namely 8 and 9 were shown the lower average volumes of trees (≤40m3) per hectare, respectively. Throughout the whole compartment (from 1-9), the number of trees were similar.

Fig. 6. Average volume of trees per hectare at 0.625% sampling intensity



3.2. Compare analysis on the variation percentage at different sampling intensity

Comparison of the existing inventory methods which are 3.0% and 0.625% with the newly proposed sampling methods; 1.5%, 0.75% sampling intensities were made. In comparison of 3.0% with 1.5% and 0.75% sampling intensity methods, there was no statistical difference and was statistically acceptable. And in contrary, comparison of 3.0% with 0.625%; 0.625% with 1.5% and 0.625% with 0.75% sampling intensity were shown statistically difference and not acceptable.

3.2.1 Comparative analysis on the variation between 3.0% with 1.5% sampling intensity

The first section, table 4 shown that statistics significance inventories between 3.0% method with 1.5% sampling intensity results, there are a total volume of 24,373.62 cubic meters (or 1,533 trees), 249 sample plots, the average volume of trees was 97.88 m^3/ha, 70.13 of the standard deviation and 4.44 of standard error of mean per hectare in the 3.0% sampling intensity; and in contrary, inventory was carried out at 1.5% sampling intensity, there are 11,485.34 cubic meters (or 755 trees), 122 sample plots, average volume of trees was 97.09 cubic meters per hectare, 73.77 of the standard deviation and 6.68 standard error of the mean per hectare.

Table 4. Comparison analysis on the variation between 3.0% with 1.5% sampling intensity

Group		N	Mean	Std. Deviation	Std. Error Mean
Sampling intensity	3.0%	249	97.88	70.13	4.44
	1.5%	122	97.09	73.77	6.68

The second section, table 5 shown that statistically independent results. Since .709>0.05 (Sig. is higher than our chosen significantly level a=0.05), the average volume of trees was .793cubic meter and 8.02 standard error per hectare; 95% confidence interval is between -15.015 to 16.60 of the mean difference. The alternative was no significantly different between ($t_{229.86} \neq 0.99$, P>0.05), which does contain zero and this agrees with the big p-value of the significance test.

Table 5. Statistically significance on the variation at 3.0% with 1.5% sampling intensity

Group	Levene's Test for Equality of Variances		t-test for Equality of Mean						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff	95% C.I. Lower	Upper
Equal variances assumed	.140	.709	.101	369	.920	.793	7.88	-14.71	16.29
Equal variances not assumed			.099	229.86	.921	.793	8.02	-15.01	16.60

3.2.2 Comparative analysis on the variation between 3.0% to 0.75% sampling intensity

The table 6 shown that inventory was carry out at 0.75% sampling intensity, there are number of 64 sample plots, the average volume of trees was 99.24 cubic meters, 74.72 of the standard deviation and 9.340 standard error of the mean per hectare in the forest inventory results.

Table 6. Comparison analysis on the variation between 3.0% with 0.75% sampling intensity

Group		N	Mean	Std. Deviation	Std. Error Mean
Sampling intensity	3.0%	249	97.88	70.13	4.444
	0.75%	64	99.24	74.72	9.340

And on the other hand, table 7 show that carry out inventoried at 3.0% with 0.75% sampling intensity method is similar. Since .544 > 0.05, the alternative was no significantly different between ($t_{93.53} \neq$ - 0.132, P>0.05), the average volume of trees was -1.362 cubic meter, 10.34 standard error of the mean and the 95% confidence interval between -21.90 with 19.17 of mean difference, which does contain zero and this agrees with the big p-value of the significance test.

Table 7. Statistically significance on the variation at 3.0% to 0.75% sampling intensity

Group	Levene's Test for Equality of Variances		t-test for Equality of Mean						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff	95% C.I. Lower	Upper
Equal variances assumed	.368	.544	-.137	311	.891	-1.362	9.962	-20.96	18.24
Equal variances not assumed			-.132	93.53	.986	-1.361	10.344	-21.90	19.17

3.2.3 Comparative analysis on the variation between 3.0% with 0.625% sampling intensity

Table 8 show that inventory was carried out at 0.625% sampling intensity, there are 54 sample plots, the average volume of trees was 68.97 m^3/ha, 46.40 of the standard deviation and there were 6.31 standard error per hectare of the mean difference in the forest inventoried results.

Table 8. Comparative analysis on the variation between 3.0% with 0.625% sampling intensity

Group		N	Mean	Std. Deviation	Std. Error Mean
Sampling intensity	3.0%	249	97.88	70.13	4.44
	0.625%	54	68.97	46.40	6.31

And table 9 shown that statistically compared between 3.0% with 0.625% sampling intensity method. Since .016<0.05, (Sig. is less than our chosen significance level a=0.05) the average volume of trees was 28.91 cubic meters and 7.72 of the standard error per hectare and 95% confidence interval between 13.61 to 44.20 of the mean difference, there was significant difference between ($t_{122.612}$=3.744, P < 0.05), which does not contain zero; this agrees with the small p-value of the significance test

Table 9. Statistically significance on the variation at 3.0% with 0.625% sampling intensity

Group	Levene's Test for Equality of Variances		t-test for Equality of Mean						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff	95% C.I. Lower	95% C.I. Upper
Equal variances assumed	7.015	.009	2.585	116	.011	30.27	11.71	7.07	53.46
Equal variances not assumed			2.685	107.14	.008	30.27	11.27	7.92	52.62

3.2.4 Comparative analysis on the variation at 0.625% to 1.5% sampling intensity

Table 10 shown that statistically significance inventory between 0.625% methods with 1.5% sampling intensity results, included a total of 122 sample plots, the average volume of trees of 97.09cubic meters, the standard deviation of 73.78 and the standard error of 6.68 of the mean difference, in contrary; there are a total of 54 sample plots; the average volume of trees was 68.97cubic meters, were 46.40 of standard deviation and 6.31 of the standard error of the mean difference for 0.625% sampling intensity results.

Table 10. Compare analysis on the variation between 0.625% with 1.5% sampling intensity

Group		N	Mean	Std. Deviation	Std. Error Mean
Sampling intensity	1.5%	122	97.09	73.779	6.679
	0.625%	54	68.975	46.401	6.314

Table 11. Statistically significance on the variation between 0.625 with 1.5% sampling intensity

Group	Levene's Test for Equality of Variances		t-test for Equality of Mean						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff	95% C.I. Lower	95% C.I. Upper
Equal variances assumed	6.135	.014	2.581	174	.011	28.11	10.89	6.61	49.61
Equal variances not assumed			3.058	153.68	.003	28.11	9.19	9.95	46.27

Table 11 shown that statistically compared between 0.65% with 0.75% sampling intensity method results. Since .014<0.05 (Sig. is less than our chosen significance level a=0.05), the null was equal variance not assumed, the average volume of trees was 28.11cubic meters and 9.19 of the standard error and 95% confidence interval between 9.95 to 46.27 of the mean difference. There was significantly between (t153.68=3.059, P < 0.05) of the significant difference, which does not contain zero, this agrees with the small p-value of the significance test.

3.2.5 Comparative analysis on the variation between 0.625% with 0.75% sampling intensity

Table 12 shown that carry out forest inventories at 0.625% to 0.75% sampling intensity results. There are 54 sample plots; the average volume of trees was 68.97cubic meters, 46.40 of the standard deviation and 6.31 of the standard error per hectare in each forest compartment inventories at 0.625% sampling intensity method. In contrary, there are a total of 64 sample plots, the average volume of trees was 99.25cubic meters, 74.72 of the standard deviation and 9.34 of the standard error per hectare in each compartment in the 0.75% sampling intensity method results.

Table 12. Compare analysis on the variation between 0.625% with 0.75% sampling intensity

Group		N	Mean	Std. Deviation	Std. Error Mean
Sampling intensity	0.75%	64	99.248	74.726	9.340
	0.625%	54	68.975	46.401	6.314

Table 13 shown that statistically compared between 0.625% with 0.75% sampling intensity. Since .009<0.05 (Sig. is less than our chosen significance level a=0.05), the null was equal, no variance assumed, the average volume of trees was 30.27 cubic meters and 11.27 standard error per hectare and 95% confidence interval at 7.92 to 52.62 of the mean difference, there was significantly between (t107.141=2.685, P < 0.05) of the difference, which does not contain zero and this agrees with the small p-value of significance test.

Table 13. Statistically significance on the variation between 0.625% with 0.75% sampling intensity

Group	Levene's Test for Equality of Variances		t-test for Equality of Mean						
								95% C.I.	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff	Lower	Upper
Equal variances assumed	7.015	.009	2.585	116	.011	30.27	11.71	7.07	53.46
Equal variances not assumed			2.685	107.141	.008	30.27	11.27	7.92	52.62

IV. Conclusions and Recommendations

In forest management system, a detailed forest inventory is required for decisions about the future management of the stands. A detailed inventory often entails the requirement of visiting every tree, for the precise estimates of volume and value (John et al., 2002). To support forest inventory, there are many factors that determine the final cost of modeling and mapping tree canopy cover nationwide (John et al., 2010). So, forest monitoring has become a key issue in national and international environmental and developmental policy process (Tewari, 2016). Decision on the sampling method is important for socioeconomic and environmental values of forests.

Because, the sampling design and plot design used are key to precise estimates of changes in forest (Charles, 1998), forest resources can be assessed using intensity-based forest inventories instead of sampling error based inventories (Bogdan, 2013). In Laos PDR, 3.0% intensity was popularly used during the 2000s' and now it is replaced with 0.625% in Production Forest Areas (PFAs). I assumed the existence of drawbacks of both intensity levels and so in this study, tried to propose two intermediary levels of sampling intensities (0.75 and 1.5%) and evaluated their significance in relation to the previously practiced sampling intensities (0.625 and 3.0%).

The results revealed the non-significant difference between 3% and 1.5% sampling intensities (P = 0.709), between 3% and 0.75% (P = 0.544). However, the results were significantly different for 3% vs 0.625% (P = 0.009), 1.5% vs 0.625% (P = 0.014) and 0.75% vs 0.625% (P = 0.009). The result exhibited that the sampling intensity 0.75% was not different from 3%. This is why, 0.75% sampling intensity exhibited the similar level of inventory as that of 3%. On the other hand, both 3% and 0.75% were significantly different from 0.625% sampling intensity. This means, the 0.625% sampling intensity can't result into the high level of precision as provided by 0.75% and 3%. Since, 0.75% is equivalent to the traditional 3% sampling method, 0.75% sampling intensity could be recommended over 3% as well as over 0.625%.

As the sample should be represented in the sense that each sampled unit will represent the characteristics of a known number of units in the population (Bobbie, 2007). Sampling is needed to save resources and make the work easier and achievable (Annika and Matti, 2006). While maintaining the forest inventory also, samplings are carried out at different level of intensities. Based on the result presented in this study, 3% and 0.75% sampling intensity result into similar inventory level. It is obvious that the lower level of inventory sampling intensity incurs less effort, time and cost. For the PFAs of Lao PDR, 0.75% sampling could be recommended over the traditional intensities.

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